



ELECTRONIC ENDOSCOPE

RELATED APPLICATION

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~~This is application is a Continuation-in-part of application~~

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BACKGROUND OF THE INVENTION

This invention relates generally to endoscopes and more particularly to electronic endoscopes.

As is known in the art, an endoscope generally includes an elongated hollow tube having a proximal or viewing end and a distal end. An optical path, including a plurality of lenses is disposed in the tube. An image provided to the distal end of the tube is transmitted along the optical path to the proximal end of the tube. The proximal end of the tube and thus the optical path typically terminate in an eye piece or in an objective plane of a microscope.

As is also known, such endoscopes may be used by physicians and others to view anatomical features of internal organs in a body cavity. In such applications, the physician inserts an endoscope into the body cavity of a patient to provide a clear view of an anatomical feature or body organ of the patient. This is especially true in the case of a surgeon who may have the need to see details of the anatomical features upon which a surgical procedure is to be performed.

As is also known, video cameras have taken a greater role in the surgical theater with the advent of lighter, smaller and higher

1 resolution video cameras. Endoscopes may be fitted with such video  
2 cameras to allow the physician to view anatomical features of  
3 interest on a video monitor. Thus, there exists a trend to  
4 terminate the optical path of the endoscope in a video camera which  
5 may in turn be coupled to a video monitor.

6 One problem with such endoscopes however, is that each of the  
7 lenses in the optical path generally reflect from each surface  
8 thereof up to 1.5 percent (1.5%) of the light incident on each  
9 lens surface. When it is necessary or desirable to increase the  
10 length of the endoscope, it is necessary to increase the number of  
11 lenses in the optical path. An optical path having a large number  
12 of lenses provides a relatively large transmission loss to an image  
13 which is transmitted along the optical path from the distal end to  
14 the proximal end of the endoscope. This is especially true when  
15 the lenses are provided having a relatively small diameter. Thus,  
16 the image viewed on a video monitor coupled to the proximal end of  
17 the endoscope, for example, is relatively dim.

18 Furthermore, the lenses in the optical path generally reduce  
19 the contrast ratio and resolution of the image and also provide  
20 chromatic aberrations and geometrical distortions of the image.  
21 Moreover, it becomes increasingly more complex and difficult to  
22 align each of the lenses included in the optical path. This leads  
23 to an increase in the cost of manufacturing the endoscope.

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1 terminated substantially coincident with the proximal end of the  
2 first tube and a distal end of the second tube terminated at an  
3 angle. The endoscope further includes an optical path disposed in  
4 and coupled to the distal end of the second tube and a  
5 photodetector disposed in and coupled to the distal end of the  
6 first tube. With this particular arrangement, an endoscope having  
7 a 360 degree field of view while transmitting images to a video  
8 monitor in a constant orientation is provided. The second tube  
9 having the optical path disposed therein may be rotated via a knob  
10 coupled thereto while the photodetector, which may be provided for  
11 example as a CCD image sensor, remains in a fixed position and is  
12 not rotated. Thus, the second tube may be rotated 360 degrees  
13 about a central longitudinal axis while the image transmitted to  
14 and viewed on the video monitor remains in a constant orientation.  
15 Furthermore, a field widening lens may be disposed in an aperture  
16 of the angled termination of the second tube.

17 In accordance with a still further aspect of the present  
18 invention a stereoscopic endoscopic viewing system includes a first  
19 hollow tube having a proximal end and a distal end, a first window  
20 disposed in an aperture of the distal end of the first tube and a  
21 optical train disposed proximate the window in the distal end of  
22 the first tube. A first photodetector is disposed proximate the  
23 optical path in the distal end of the first tube and a rod is  
24 coupled to the first hollow tube. The stereoscopic endoscopic  
25 viewing system further includes a second hollow tube having a  
26 proximal end and a distal end with the second hollow tube being

1 coupled to and movable in response to the rod, a second window  
2 disposed in an aperture of the distal end of the second tube, a  
3 second optical train disposed proximate the window in the distal  
4 end of the second tube and a second photodetector disposed  
5 proximate the second optical train in the distal end of the second  
6 tube. With this particular arrangement, a stereoscopic endoscopic  
7 viewing system having increased separation between a pair of  
8 optical trains is provided. The first and second tubes of the  
9 endoscope may be aligned along a single longitudinal axis and  
10 inserted into a body cavity of a patient for example through a  
11 cannula as is generally known. Since the first and second tubes  
12 are concentrically aligned along a single longitudinal axis the  
13 endoscope may be inserted through a relatively small opening in a  
14 body wall of the patient. After the first and second tubes are  
15 inserted through the patient's body wall and into a body cavity  
16 through the cannula, the second tube may be rotated about the rod  
17 until the longitudinal axis of both the first and second tubes are  
18 separate and substantially parallel. The second tube may then be  
19 retracted via the rod a predetermined distance until the distal end  
20 of the second tube and the distal end of the first tube are  
21 substantially aligned in a single plane. The distance between the  
22 central longitudinal axis of the first tube and the central  
23 longitudinal axis of the second tube may be significantly wider  
24 than in conventional single tube systems having adjacently disposed  
25 optical trains. By providing a relatively wide separation between  
26 the optical paths, the stereoscopic endoscopic viewing system

1 provides a better sense of depth perception or three-dimensional  
2 sensation when the images are converted to electrical signals via  
3 the photodetectors and coupled to a video monitor.

4 In accordance with a still further aspect of the present  
5 invention an endoscope includes a first tube having a proximal end  
6 and a distal end and a channel therethrough, a rod, and a second  
7 hollow tube having a proximal end juxtaposed the distal end of the  
8 first hollow tube and a distal end with the second hollow tube  
9 being coupled to and movable in response to the rod. The endoscope  
10 further includes a window disposed in an aperture of the distal end  
11 of the second tube, an optical train disposed proximate the window  
12 in the distal end of the second tube and a photodetector disposed  
13 proximate the optical train. With this particular arrangement an  
14 endoscope having an operative channel is provided. The central  
15 longitudinal axis of the first and second tubes may be aligned and  
16 the endoscope may be disposed through a cannula into a small  
17 incision made in a body wall of a patient to view a body cavity of  
18 the patient. The second tube may then be rotated about the rod  
19 such that a central longitudinal axis of the first tube and a  
20 central longitudinal axis of the second tube are substantially  
21 parallel and the channel in the first tube is exposed. The second  
22 tube may then be retracted via the rod such that the distal end of  
23 the first tube and the distal end of the second tube are  
24 substantially aligned in a single plane. Thus a surgeon for  
25 example may insert a surgical instrument through the operative  
26 channel of the endoscope and operate on a predetermined region of

1 the patient. Furthermore, by rotating the second tube to expose  
2 the operative channel provided in the first tube, the operative  
3 channel may be provided having a relatively large diameter.  
4 Furthermore by placing the photodetector, which may be provided as  
5 a charge couple device image sensor for example, proximate the  
6 optical train in the distal end of the second tube, the operative  
7 endoscope of the present invention is significantly more light  
8 sensitive and provides less distortion to an image than do  
9 conventional designs. Thus, the operative endoscope has an  
10 operative channel having a larger diameter and provides a minimum  
11 amount of image degradation.

#### 12 BRIEF DESCRIPTION OF THE DRAWINGS

13 The foregoing features of this invention as well as the  
14 invention itself may be more fully understood from the following  
15 detailed description of the drawings in which:

16 FIG. 1 is a side view of an electronic endoscope;

17 FIG. 1A is a cross sectional view of a portion of the  
18 electronic endoscope of FIG. 1;

19 FIG. 1B is a front view of the electronic endoscope of FIG. 1  
20 taken along lines 1B-1B of FIG. 1;

21 FIG. 2 is cross-sectional view of an endoscope having an  
22 integral illumination assembly;

23 FIG. 2A is a front view of the endoscope of FIG. 2 taken along  
24 lines 2A-2A of FIG. 2;

1 FIG. 3 is a side view of an endoscope having a rotatable  
2 optical train;

3 FIG. 3A is a cross sectional view of a portion of the  
4 endoscope of FIG. 3;

5 FIG. 3B is a front view of the endoscope of FIG. 1;

6 FIG. 4 is a top view of a stereoscopic endoscopic viewing  
7 system;

8 FIG. 4A is a front view of the stereoscopic endoscopic system  
9 of FIG. 4 of FIG. 1;

10 FIG. 4B is a top view of a portion of the stereoscopic  
11 endoscopic viewing system of FIG. 4A;

12 FIG. 4C is a front view of the stereoscopic endoscopic system  
13 of FIG. 4B;

14 FIGS. 4D and 4E are perspective views of a portion of a  
15 stereoscopic viewing system which may be of the type shown in  
16 FIG. 4;

17 FIG. 5-5D are a series of views of an endoscope having an  
18 operative channel;

19 FIGS. 6-~~6C~~<sup>6B</sup> are a series of views of an endoscope having a zoom  
20 lens;

21 FIG. 7 is a view of an alternate embodiment of an endoscope  
22 having a zoom lens;

23 FIG. 7A is an alternate embodiment of an endoscope having a  
24 focusing mechanism which may be used in the endoscope of FIG. 7;

25 FIG. 7B is a front view of the endoscope of FIG. 7A;



1 FIGS. 7C - 7E are a series of views of an endoscope having a  
2 rotatable optical train and a focusing mechanism;

B 3 FIGS. 8-<sup>8C</sup>~~8C~~ are a series of views of an endoscope having a  
4 parasitic set of fiber optic cables; and

5 FIGS. 9 and 9A are front views of an alternate embodiment of  
6 an endoscope having parasitic illumination fibers.

7 DESCRIPTION OF THE PREFERRED EMBODIMENTS

8 Referring now to FIGS. 1-1B, in which like elements are  
9 provided having like reference designations throughout the several  
10 views, an endoscope 10 includes a handle 16 having coupled to a  
11 back end 16a thereof an illumination fiber guide 12 and an  
12 electrical cable 14 which may be of the multiconductor type for  
13 example. A hollow tube 18 having a proximal end 18a and a distal  
14 end 18b is coupled to a front end 16b of the handle 16.

15 As can be more clearly seen in FIG. 1A, an aperture in the  
16 distal end 18B of the endoscope 10 has disposed therein a  
17 protective window 19 which preferably is manufactured from a  
18 material transparent to light. An optical train generally  
19 denoted 20 includes a first lens 20a disposed proximate the  
20 window 19, a second lens 20b and a third lens 20c disposed as  
21 shown.

22 A photodetector 22, which may be provided for example as a  
23 charge couple device (CCD) image sensor, is disposed at an end of  
24 the optical path 20 opposite the window 19. Such CCD image sensors  
25 are commercially available, and the operation of such devices is

1 well known to those of ordinary skill in the art. For example a  
2 device manufactured by Panasonic Corporation and identified as part  
3 number MN3715FC may be used.

4 A plurality of electrical conductors 24a, 24b, 24c generally  
5 denoted 24 couple the photodetector 22 to the electrical cable 14.  
6 Second end of the electrical cable 14 may be coupled to a separate  
7 signal processing unit (not shown) as is generally known. A  
8 plurality of illumination fibers 28a - 28N, generally denoted 28,  
9 are fed through the fiber guide 12 and terminate in the distal  
10 end 18b of the endoscope 10.

11 Referring briefly to FIG. 1B, the tube 18 is here provided as  
12 a pair of coaxial tubes 21a, 21b. An annular region 23 defined by  
13 an inner surface of the tube 21a and an outer surface of the  
14 tube 21b has disposed therein a plurality of illumination  
15 fibers 28.

16 Referring again to FIG. 1, a second end of the illumination  
17 fiber guide 12 is connected to a light source (not shown) which  
18 provides illuminating light to the optical fibers 28. A second end  
19 of the illumination fibers 28 are exposed through the annular  
20 aperture 23 to provide illumination to a region in front of the  
21 distal end 18b of the tube 18.

22 In use, the endoscope 10 may be inserted through a cannula and  
23 subsequently through an incision made in a body wall of a patient,  
24 for example, and disposed in a body cavity of the patient.  
25 Illuminating light fed from the light source (not shown) to the  
26 illumination fiber guide 12 travels along the fiber optic bundle 28

1 and illuminates a region in the patient's body cavity where the  
2 distal end 18b of the tube is disposed.

3 The optical train 20 receives light reflected from the body  
4 cavity through the window 19 and transmits an image from the distal  
5 end 18b of the tube 18 to the photodetector 22 via the optical  
6 train 20. The photodetector 22 converts the optical signals fed  
7 thereto to electrical signals which are fed on the electrical  
8 signal path 24 to the electrical cable 14. As mentioned above, the  
9 second end of the electrical cable 12 may be coupled to a signal  
10 processing unit and subsequently to a video monitor (not shown) as  
11 is generally known to allow the surgeon, for example, to view the  
12 area under operation. The window 19 may serve as an optical filter  
13 having filter characteristics selected to attenuate light which  
14 occurs at predetermined portions of the visual spectrum such that  
15 an image having desirable contrast and color may be viewed on the  
16 video monitor.

17 Conventional endoscopic viewing systems may typically include  
18 a plurality of lenses having relatively small diameters with each  
19 of the lenses arranged precisely in sequence to transmit an image  
20 from the distal end of the endoscope to a proximal or viewing end  
21 of the instrument where the image is focused onto the eye. In  
22 order to attach a video camera to the endoscope it is necessary to  
23 have an optical relay adapter to refocus the image onto the video  
24 camera. In conventional endoscopes, such small diameter lenses  
25 must be manufactured and assembled in a very precise manner.

1 In the present invention, however, the need for a complex  
2 optical train is eliminated because the photodetector 22 is  
3 disposed at the distal end of the endoscope 10. The replacement  
4 of the complex optical train with a relatively simple optical  
5 train 20 reduces the number of optical interfaces through which  
6 light must travel. This results in the endoscope of the present  
7 invention having a concomitant reduction in the attenuation of an  
8 image transmitted through the optical train 20. Thus, the light  
9 sensitivity of the endoscope 10 is significantly increased over  
10 conventional systems.

11 Furthermore, by providing the endoscope 10 having the shorter  
12 optical train 20 there is a significant reduction in the amount of  
13 chromatic aberration and geometrical distortions provided to an  
14 image. Moreover, the endoscope 10 may be provided in any length  
15 with no concomitant reduction in performance.

16 In conventional systems, the number of lenses which comprise  
17 the optical path is directly proportional to the length of the  
18 endoscope. The amount of light transmitted along the optical path  
19 is attenuated due to reflection and transmission losses resultant  
20 from each lens in the optical path. Thus, in conventional systems  
21 having a relatively long and complex optical train, light which is  
22 transmitted from the distal end to the proximal end of the  
23 endoscope may be highly attenuated.

24 In the present invention however, the image is converted to  
25 electrical signals in the distal end of the endoscope 10. Such  
26 electrical signals may be transmitted along an endoscope of any

length with relatively little, if any, increase in signal loss. Thus, like optical trains having relatively low reflection and transmission loss characteristics may be used in endoscopes of any length with no corresponding reduction in image quality.

Furthermore, placing the photodetector 22 at the distal end 18b of the tube 18 reduces the amount of image eccentricity and eliminates the need for an optical relay coupling device which may provide image obscuration due to fogging during a surgical procedure. Such fogging generally occurs due to liquid sterilization and a wetness of the operational field due to irrigation of the operational field. Image eccentricity in conventional systems may be caused by the optical misalignment of the camera, the optical relay coupler, and the endoscope.

Referring now to FIGS. 2 and 2A an endoscope 30 includes a handle 32 having coupled to a back end 32a thereof an electrical cable 37 and having coupled to a front end 32b thereof a hollow tube 34 which may be similar to the tube 18 described above in conjunction with FIGS. 1-1B. Disposed in an aperture of a distal end 34b of the tube 34 is a window 36 and proximate the window 36 is disposed an optical train 38 and a photodetector 42. The window 36, optical train 38 and photodetector 40 may be similar to the window 19 (FIG. 1), the optical train 20 (FIG. 1) and the photodetector 22 (FIG. 1) described above in conjunction with FIGS. 1 - 1B. The photodetector 40 may be coupled to the electrical cable 37 via an electrical signal path 42 which includes electrical conductors 42a, 42b and 42c.

1 A light source 43 is disposed in a cavity region defined by  
2 the walls of the handle 32 of the endoscope 30. The handle 32 may  
3 be fabricated from a thermally conductive material such as aluminum  
4 for example to thus act as a heat sink to dissipate thermal energy  
5 by the light source 43. The electrical cable 37 includes a power  
6 cable 38 coupled to the light source 43. The light source 43 has  
7 coupled thereto fiber optic bundles 42a and 42b which are fed into  
8 the proximal end 34a of the tube 34. Although not shown in FIG. 2,  
9 a switch may be disposed on the handle and coupled between the  
10 power cable 38 and the light source 43 to thus provide a means for  
11 turning the light source 43 on and off.

12 As is clearly shown in FIG. 2B, the tube 34 is provided from  
13 a pair of coaxial tubes 35a, 35b. An inner surface of the tube 35a  
14 and an outer surface of the tube 35b defined an annular region 29.  
15 The fiber optic bundles 42a and 42b are dispersed and terminate in  
16 the distal end 34b of the tube 34 to provide a plurality of  
17 illumination fibers 44 evenly distributed in the annular region 29  
18 between the pair of coaxial tubes 35a, 35b. The illumination of  
19 the viewing region is thus provided by light transmitted from the  
20 light source 43 to the fiber optic bundles 42a, 42b and  
21 consequently to the ends of the optical fibers 44.

22 As described above in conjunction with FIG. 1, by providing  
23 the photodetector 22 in the distal end of the endoscope 30 the  
24 transmission loss of the optical path is greatly reduced.  
25 Consequently, less light is required to provide adequate  
26 illumination in a desired region to be viewed such as a body

1 cavity. Therefore, the optic light source 43 need not be as  
2 powerful as light sources used in conventional endoscopic viewing  
3 systems and may thus be disposed in the internal cavity region of  
4 the handle 32.

5 Referring now to FIGS. 3 - 3B, in which like elements are  
6 provided having like reference designations throughout the several  
7 views, an endoscope 50 includes a handle 52 having an electrical  
8 cable 53 coupled to a rear end thereof. It should be noted that  
9 the handle 52 here includes in an internal cavity region in which  
10 may be disposed an illumination assembly (not shown) similar to the  
11 illumination assembly 43 described above in conjunction with  
12 FIG. 2.

13 Alternatively, in the case where an illumination assembly is  
14 not disposed in a cavity region of the handle 52 an illumination  
15 guide (not shown) similar to the illumination guide 14 described  
16 above in conjunction with FIG. 1 may be coupled to the handle 52.  
17 Coupled to a front end of the handle 52 is a tube 54 having a  
18 proximal end 54a and a distal end 54b.

19 As may be more clearly seen in FIG. 3A, the tube 54 is  
20 provided from an inner tube 56 having a proximal end 56a (not  
21 shown) and a distal end 56b and an outer tube ~~assembly~~ 57 having a  
22 proximal end 57a (not shown) and a distal end 57b. The proximal  
23 end of the inner tube is fixed to the handle 52 and an optics train  
24 rotating knob 55 (FIG. 3) is coupled to the proximal end of the  
25 outer tube ~~assembly~~ 57. A photodetector 59 is disposed in the  
26 distal end 57b of the inner tube 56 and the photodetector 59 may

1 thus be maintained in a predetermined orientation with respect to  
2 the handle 52 such that an image provided to the photodetector 59  
3 may be transmitted via <sup>an</sup> the electrical signal path 63, in the same  
4 orientation to a viewing system (not shown). <sup>63</sup>

5 A field widening lens 62 is disposed over an aperture in the  
6 distal end 57b of the outer tube ~~assembly~~ 57. The field widening  
7 lens 62 may have the filtering characteristics similar to the  
8 window 19 described above in conjunction with FIG. 1. A prism 60  
9 is disposed in the distal end 57b of the outer tube ~~assembly~~ 57 to  
10 align an image fed thereto through the window field widening  
11 lens 62 with the lens system 58 which includes first and second  
12 lenses 58a and 58b as shown. Those of skill in the art will  
13 recognize of course that lens system 58 may include more or fewer  
14 lenses than those shown. The field widening lens 62, prism 60 and  
15 lens system 58 are fixed to the outer tube ~~assembly~~ 57 and  
16 cooperate to provide an optical train ~~63~~. Thus, the outer tube  
17 ~~assembly~~ 57 and consequently the optical train ~~63~~ may be rotated  
18 via the optical train rotating knob 55. Since the photodetector 59  
19 is disposed in a fixed position within the inner tube 56, an image  
20 seen on a viewing system (now shown) coupled to the  
21 photodetector 59 will not become disoriented with the rotating  
22 optical train ~~63~~.

23 The outer tube 57 may have the distal end 57b thereof  
24 terminated at an angle typically of about 15 to 45 degrees, however  
25 the termination angle may be in the range of 1 to 90 degrees. The  
26 angle of the prism face 60a is selected to correspond to the angle



1 at which the distal end 57b of the tube 57 is terminated. Thus,  
2 the rotation of the tube 57 about its central longitudinal axis  
3 allows the surgeon to view a wider field of view. That is, the  
4 surgeon may view both forward and side regions of a viewing area by  
5 simply rotating the tube 57 and consequently the lens <sup>system</sup> ~~train~~ 58,  
6 prism 60 and field widening lens 62 via the rotating knob 55.

7 For example, if the distal end of the tube 57 is terminated at  
8 an angle of 45° the endoscope 50 provides the surgeon having a view  
9 of a region at an angle of 45° from its central longitudinal axis  
10 and the surgeon is not limited to a straight view. Furthermore, in  
11 some applications it may be desirable for portions of either or  
12 both of the tubes 56, 57 proximate the proximal end of the tube 54  
13 to be fabricated from a flexible material. It should be noted  
14 however that field widening lens 62, prism 60, lens <sup>system</sup> ~~train~~ 58 and  
15 photodetector 59 should be aligned to provide proper optical  
16 focusing. When the outer tube 57 is rotated via the knob 55 the  
17 image which is transmitted through the angled end of the tube 57 is  
18 directed via the prism 60 and the lens system 58 to the  
19 photodetector 59 which may be provided as a CCD image sensor for  
20 example.

21 As described above in conjunction with FIG. 1, the  
22 photodetector 59 converts the optical signals to electrical signals  
23 and transmits them via electrical conductors 63a-63c, generally  
24 denoted 63, to the electrical cable 53 and subsequently to a video  
25 system or viewing system (not shown) coupled to the electrical  
26 cable 53. Thus the endoscope 50 simplifies the maneuvering and

manipulation required of a surgeon, for example, to survey a 360° field of view while providing pictures having a constant orientation to a viewing system.

The prism 60 is here provided from three separate glass pieces joined to provide first and second reflecting surfaces 61a, 61b. Light enters the distal end of the tube 54 and enters the prism 60 through prism face 60a. The light ends the prism 60 and reflects off of the first reflective surface 61a, then reflects off the second reflective surface 61b and exits the prism 60 through prism face 60b. The light then passes into the lens <sup>system</sup> train 58. As mentioned above, the lens <sup>system</sup> train 58 is provided from <sup>two</sup> ~~three~~ separate lenses <sup>58a and 58b</sup> ~~58a, 58b and 58c~~. Those of ordinary skill in the art will recognize of course that the lens <sup>system</sup> train 58 may be provided from fewer or more lenses and the embodiment described herein is exemplary only.

In operation, the light reflected from the prism surface 61a is directed through the prism face 60b and toward the ~~convex~~ ~~concave lens 58a which directs the light toward the~~ doublet formed by the convex-concave <sup>58b</sup> and convex-convex lens <sup>58a</sup> ~~58c~~. The light is directed out of a second surface of the lens 58a and onto the photodetector 59 which converts the light image to electrical signals. The electrical signals are fed into an electrical signal processing system (not shown) and subsequently fed to a viewing system (not shown) via the electrical signal path 63 in a manner similar to that described above in conjunction with FIG. 1.

1 Referring now to FIGS. 4-4E, in which like elements are  
2 provided having like reference designations throughout the several  
3 views, a stereoscopic endoscopic viewing system 66 includes a  
4 handle 68 having an electrical cable 70 coupled to a rear surface  
5 thereof and having a lever 72 exposed through a top surface  
6 thereof. It should be noted that the handle 68 is here provided  
7 having an internal cavity region (not shown) in which is disposed  
8 an illumination assembly (not shown) similar to the illumination  
9 assembly 43 described above in conjunction with FIG. 2.  
10 Alternatively, in the case where an illumination assembly is not  
11 disposed in the handle 68 an illumination guide similar to the  
12 illumination guide 14 described above in conjunction with FIG. 1  
13 may be coupled to the back surface of the handle 68.

14 A first hollow elongated tube 74 is coupled to a front surface  
15 of the handle 68. A rod 76 here having a bore therethrough is  
16 disposed along a surface of the tube 74 and extends into the  
17 handle 68 and is coupled to the lever 72. A window 79 is disposed  
18 over an aperture in the distal end 74b of the tube 74. The  
19 window 79 may provide filtering characteristics similar to those of  
20 the window 19 described above in conjunction with FIG. 1. Disposed  
21 in the distal end of the tube 74 is a first optical train 77 and a  
22 photodetector 78 which may be provided as a CCD image sensor, for  
23 example.

24 A second tube 84 has a proximate end 84a juxtaposed the distal  
25 end 74b of the first tube 74. The second tube 84 has disposed  
26 therein a second optical train 82 and a second photodetector 83.

1 A second window 85 is disposed over an aperture of a distal end 84b  
2 of the tube 84 as shown.

3 Referring briefly to FIGS. 4A and 4C, the illumination  
4 fibers 80a-80N generally denoted 80 are disposed in an annular  
5 region 74' of the tube 74 in a manner similar to that described  
6 above in conjunction with FIG. 1B.

7 In FIG. 4, the second tube 84 is shown having a central  
8 longitudinal axis substantially aligned with a central longitudinal  
9 axis of the first tube 74. In operation, the tubes 74 and 84 are  
10 arranged such that the central longitudinal axis of each of the  
11 tubes 74, 84 fall on a single line as shown in FIG. 4 and may be  
12 inserted through a cannula through an incision made in a body wall  
13 of a patient for example. Once the tubes 74, 84 are passed through  
14 the cannula and are disposed in a body cavity of the patient, the  
15 lever 72 may be used to rotate the second tube 84 about the rod 76.

16 As may be more clearly seen in FIG. 4B, the second tube 84 may  
17 be rotated via the rod 76 until the central longitudinal axis of  
18 the tube 84 is adjacent and parallel with the central longitudinal  
19 axis of the first tube 74 and the window 79 of the first tube 74 is  
20 fully exposed. The lever 72 may be used to retract the distal  
21 end 84b of the second tube 84 until the distal end 84b of the  
22 second tube 84 and the distal end 74b of the first tube 74 are  
23 substantially aligned in a single plane as shown in FIG. 4D.

24 The image transmission elements may each be disposed at a  
25 slight angle toward each other such that the fields of view  
26 converge a single point. The angle may be present in the tubes 74,

84 to provide convergence at a predetermined nominal distance. Any resultant parallaxing for which results from viewing an object at a distance which is different than the nominal distance may be electronically compensated via a processor as is generally known to one of ordinary skill in the art

Although not shown in FIG. 4 each of the photodetectors 78 and 83 are provided having electrical connections to the electrical cable 70. A plurality of electrical wires (not shown) from the second photo detector 83 are disposed through a bore in the rod 76 and coupled to the electrical cable 70.

The images are fed as electrical signals via the photodetectors 78, 83 to a stereo video processing unit (not shown). In the stereo processing unit (not shown) the electrical signals may be combined using computerized stereographic techniques.

Referring now to FIGS. 5 - 5D, in which like elements are provided having like reference designations throughout the several views, an operative endoscope 80 includes a handle 82 having a pair of bores 81, 87 therethrough. An electrical cable 84 is coupled to a rear portion of the handle 82 in a manner and for a purpose the same as the electrical cables described hereinabove in conjunction with FIGS. 1, 2, 3 and 4. As mentioned above in conjunction with FIGS. 3 and 4, it should be noted that the handle 82 here includes in an internal cavity region (not shown) an illumination assembly (not shown) which may be similar to the illumination assembly 43 described above in conjunction with FIG. 2.

1           Alternatively, in the case where an illumination assembly is  
2   not disposed in the handle 82 an illumination guide similar to the  
3   illumination guide 14 described hereinabove in conjunction with  
4   FIG. 1 may be coupled to the handle 82.

5           A tube 86 is coupled to a front portion of the handle 82 and  
6   a rod 88 having a bore through at least a portion thereof is  
7   coupled to a top end of the tube and extends into the handle 82.  
8   The tube 86 is here shown being formed integrally as a unitary  
9   piece with the handle 82. It should be pointed out, however, that  
10   the handle 82 and the tube 86 may be formed as separate and  
11   distinct pieces and integrated using screws, epoxy or any other  
12   technique well known to those of ordinary skill in the art to join  
13   two pieces to provide one assembly. *cb*

*IN 3.0*  
14           A knob 89 disposed in a top portion of the handle 82 is  
15   coupled to a first end of the rod 88. A second end of the rod 88  
16   is coupled to a second hollow tube 90 having a proximate end 90a  
17   juxtaposed the distal end 86b of the first tube 86. A window 93 is  
18   disposed in an aperture of a distal end 90b of the second tube 90.  
19   The window 93 may provide the same filtering characteristics as the  
20   window 19 described in conjunction with FIG. 1 above. The second  
21   tube 90 is responsive to movements of the rod 88 and to movements  
22   of the knob 89. Disposed in the tube 90 is an optical train 91 and  
23   a photodetector 92.

24           A plurality of electrical wires from the photodetector 92 are  
25   disposed through the bore of the rod 88 and coupled to the  
26   electrical cable 84.

1 As may be more clearly seen in FIG. 5B, the second tube may be  
2 rotated 180° degrees via the rod 88 and positioned alongside the  
3 first tube 86. Thus, the bore 81 which passes through the  
4 handle 82 and the first tube 86 is exposed to provide an operative  
5 channel in which a surgical instrument (not shown) may be inserted.  
6 Also after the second tube 90 is rotated, <sup>the front ends of</sup> ~~a plurality of~~ fiber  
7 optic rods 83 are exposed. The optic fibers 83 illuminate a region  
8 in front of the distal portion of the endoscope 80.

9 A stop cock 94 is coupled to the back end 85b of the  
10 handle 82. As is generally known an insufflation gas, such as  
11 carbon dioxide (CO<sub>2</sub>) for example, is generally introduced into a  
12 patient to expand a body cavity and facilitate access to a surgical  
13 site. Here such gas may be introduced into the body cavity via the  
14 bore 87. Thus when no surgical instrument is disposed in the  
15 bore 81 the stop cock 94 may be closed to prevent the loss of the  
16 insufflation gas from the patients body cavity. The stop cock 94  
17 may similarly operate to close the bore 87. Alternatively separate  
18 stop cocks (not shown) may be coupled to each of the bores 81, 87  
19 to control the flow of gas through the bores 81, 87.

20 As may be more clearly seen in FIG. 5C the second tube 90 may  
21 be retracted such that the distal end 90b of the second tube 90 is  
22 substantially aligned in a single plane with the distal end 86b of  
23 the first tube 86. Thus any shadow effects caused by the tube 90  
24 are minimized.

25 In operation, when the endoscope 80 is inserted through a  
26 cannula and into a body cavity of a patient to dispose tubes 86, 90

1 in the body cavity of the patient, a central longitudinal axis of  
2 the second tube 90 is aligned with a central longitudinal axis of  
3 the first tube 86. After the tubes 86 and 90 are disposed in the  
4 body cavity of the patient however, the second tube 90 may be  
5 rotated via the knob 89 and rod 88 to expose the operative bore 81  
6 to thus allow a surgeon, for example, to pass a surgical instrument  
7 through the handle end of the bore 81 and perform surgery in the  
8 body cavity. After the surgery is complete, the surgical  
9 instrument is removed from the bore 81 and the second tube 90 may  
10 be rotated back into its original position having the central  
11 longitudinal axis substantially aligned with the central  
12 longitudinal axis of the first tube 86. The endoscope 80 may then  
13 be retracted from the body cavity and cannula

14 Thus in the case where the endoscope 80 is inserted into the  
15 body cavity through a cannula (not shown), the inside diameter of  
16 the opening in the cannula determines the maximum outside diameter  
17 of the endoscope. Thus, in an endoscope having a predetermined  
18 outside diameter, the diameter of the operative channel in the  
19 present invention may be substantially larger than the diameter of  
20 the operative channel in conventional endoscopes.

21 That is for a predetermined outside diameter, the endoscope of  
22 the present invention is provided with an operative channel having  
23 a substantially larger diameter than the operative channel of a  
24 conventional operative endoscope having the same outside diameter.  
25 Thus, the operative channel 81 may be provided having a larger  
26 diameter than conventional endoscopes while the outside diameter of



1 the tubes 86 and 90 remain the same as the outside diameter of a  
2 conventional endoscope. The surgeon, therefore, is provided with  
3 more room to insert a variety of different surgical instruments  
4 while preventing the need to provide a larger incision in the  
5 patient to accommodate an endoscope having a larger outside  
6 diameter. It will be also noted however that in some surgical  
7 procedures the operative endoscope may be used without the use of  
8 a cannula.

9 Referring now to FIGS. 6 - 6B, in which like elements are  
10 provided having like reference designations throughout the several  
11 views, an endoscope 100 includes a handle 114 having coupled to a  
12 back portion thereof an illumination fiber-guide 110. An  
13 electrical cable 112 is also coupled to the back portion of the  
14 handle 114.

15 It should be noted that the endoscope 100 here includes the  
16 illumination guide 110 coupled to the back portion of the handle  
17 114 to perform the same function as the fiber guide 14 described  
18 above in conjunction with FIG. 1. In an alternate embodiment, the  
19 endoscope 100 may be provided having an illumination assembly (not  
20 shown) which may be similar to the illumination assembly 43  
21 described hereinabove in conjunction with FIG. 2, for example,  
22 disposed in an internal cavity region of the handle 114.

23 A front portion of the handle 114 has coupled thereto a hollow  
24 tube 122. Coupled to the hollow tube is a rod 123. A bidirectional  
25 motor 118 is disposed in an internal cavity of the handle 114. The  
26 motor 118 may be coupled to the rod 123 via a ~~coupling~~

1 apparatus 120 which may be provided as a worm gear, or any other  
2 coupling apparatus well known to those of ordinary skill in the  
3 art. The motor is bi-directional <sup>so</sup> in that it may <sup>move</sup> turn the rod 123 in  
4 two opposite directions.

5 A zoom control switch 116 is coupled between the electrical  
6 cable 112 and the motor 118. When the control switch 116 provides  
7 a <sup>First</sup> conductive path between a power line 119 and the motor 118, the  
8 motor 118 causes <sup>mechanism 120 to move</sup> the control rod 123 ~~to spin~~ in a first direction. <sup>ag</sup>

9 Disposed in the distal end of the hollow tube 122 is a  
10 photodetector 124 which may be provided as a CCD image sensor for  
11 example, and a plurality of lenses 126a, 126b and 126c. The lens  
12 126b is slidably disposed in the tube 122. The rod 123 is coupled  
13 to the movable lens 126b while the lenses 126a, 126c are disposed  
14 in fixed predetermined positions within the tube 122. The lenses  
15 126a, 126b and 126c together provide a lens train 126 which directs  
16 optical signals to photodetector 124. A lens 130, which may be  
17 similar to the lens 19 described above in conjunction with FIG. 1,  
18 may be disposed in the aperture of the <sup>inner tube 122a of</sup> tube 122.

19 The optical path 126 directs light to the photodetector 124  
20 and as described above in conjunction with FIG. 1 the photodetector  
21 124 converts the light to an electrical signal which may be fed to  
22 a viewing system (not shown) via the electrical signal path 127. <sup>Provided by conductors</sup>  
23 In response to the motor 118 <sup>moving</sup> turning the rod 123, the lens 126b is  
24 moved relative to the lenses 126a and 126c in <sup>an axial</sup> a direction ~~along the~~  
25 <sup>moving</sup> longitudinal axis of the tube 122. By moving lens 126b <sup>changes</sup> the focal  
26 length of the lens train 126 ~~is also moved~~.

1 The photodetector 124 is disposed in a housing 125 that is  
2 movable within the <sup>inner tube 122 of</sup> hollow tube 122 in a direction along the  
3 longitudinal axis of the tube <sup>122</sup> 122. A second rod 129 is connected  
4 to the housing 125 and is also coupled to a second <sup>motion-translating mechanism</sup> gear box 133  
5 disposed inside the handle 114. A second bi-directional motor 135  
6 is also disposed in an internal cavity of the handle 114. The  
7 second motor 135 is coupled to the second <sup>motion-translating mechanism</sup> gear box. A focus  
8 control switch 137 is coupled between cable 112 and the second  
9 motor 135. When the switch 137 provides a first conductive path  
10 between a power source (not shown) and the motor 135, the second  
11 motor 135 causes <sup>the second motion-translating mechanism 133 to move</sup> the second control rod 129 <sup>to turn</sup> in a first  
12 direction, thus moving the photodetector 124 in a first direction  
13 along the longitudinal axis of the <sup>inner</sup> tube 122. When the switch 137  
14 provides a second conductive path between the power source (not  
15 shown) and the motor 135, the motor 135 causes the second control  
16 rod 129 to turn in a second direction, thus moving the photodetector  
17 in a second opposite direction along the longitudinal axis of the  
18 tube 122. Therefore, the photodetector 124 may be moved relative  
19 to lens train 126 to obtain optimum focus.

20 As can be more clearly seen in FIG. 6B, the lens 126b may be  
21 moved relative to the lenses 126a, 126c and the photodetector 124.  
22 Depending on the distance by which a first surface of the lens 126b  
23 is separated from a first surface of the lens 126a a varying size  
24 image is provided to the photodetector 124. Thus, the surgeon may  
25 enlarge or reduce as desired the image of a particular feature of  
26 a body part to be operated on for example.

1 Referring now to FIG. 7, an alternate embodiment of the zoom  
2 endoscope 100' is shown to include a zoom control knob 141 coupled  
3 to the rod 123 to manually move the lens 126b. Similarly a focus  
4 control lever 139 is coupled to a rod 129' to manually move the  
5 photodetector 124 in first and second opposing directions along a  
6 longitudinal axis of the tube 122. By moving the lens 126b  
7 relative to lens 126a, a particular magnification may be provided.  
8 However, such movement may defocus the viewing system. Thus, the  
9 focus control lever 139 may be used to move the photodetector 124  
10 to an appropriate focal plane to thus provide a focused system.

11 Referring now to FIGS. 7A and 7B, a distal portion of an  
12 endoscope 101 includes a lens train 126 which directs optical  
13 signals to the photodetector 124 as described above in conjunction  
14 with FIGS. 6-6B. The photodetector 124 is directly coupled to a  
15 control rod 129'. The control rod 129' may be coupled at a second  
16 end thereof as described above in conjunction with FIG. 6. It  
17 should be noted that the optical path 126 is stationary while the  
18 image sensor 124 moves along first and second longitudinal  
19 directions in response to the control rod 129'. Thus, as shown in  
20 FIG. 7B, the optical fibers 128 may be evenly distributed about the  
21 circumference of the distal end of the endoscope 101.

22 Referring now to FIGS. 7C-7E, an endoscope 150 includes a  
23 rotatable optical train 152 which may be similar to the optical  
24 train described above in conjunction with FIGS. 3-3B and a moveable  
25 image sensor 154. The optical train 152 is disposed in a fixed  
26 position of the endoscope 150 and may be rotated in a manner as

1 described in conjunction with FIGS. 3-3B above. The image sensor  
2 154, however, is moveable along first and second longitudinal  
3 directions of the endoscope in response to movements of a control  
4 rod 155 moved by a lever 156. Thus, as shown in FIG. 7E, the  
5 optical fibers 128 may be evenly distributed about the  
6 circumference of the distal end of the endoscope 150.

7 Referring now to FIGS. 8-8C, a distal portion 160 of an  
8 endoscope includes a first tube 162, a portion here being shown,  
9 and a second tube 164. The first and second tubes 162, 164 are  
10 each provided having flattened surfaces 161 and 163. A rod 166,  
11 which may be similar to the rod 76 described above in conjunction  
12 with FIG. 4, is disposed along the surfaces 161, 163 of the tubes  
13 162 and 164 and is coupled to the tube 164. The outside diameter  
14  $D_1$  (FIG. 8B) of the endoscope 160 including the control rod 166 is  
15 selected to be smaller than an inside diameter of a cannula (not  
16 shown) through which the endoscope 160 may be disposed.

17 The second tube 164 has a proximate end 164a juxtaposed the  
18 distal end 162b of the first tube 162. Disposed in an annular  
19 aperture 165 of the second tube 164 are a plurality of illumination  
20 fibers 167a through 167N generally denoted 167. The illumination  
21 fibers 167 are disposed in the annular region 165 in a manner  
22 similar to that described in conjunction with FIGS. 1B, 4A and 4C.

23 In FIG. 8, the second tube 164 is shown having a central  
24 longitudinal axis substantially aligned with a central longitudinal  
25 axis of the first tube 162. In operation, the tubes 162 and 164  
26 are arranged such that the central longitudinal axis of each of the

1 tubes 162, 164 fall on a single line as shown in FIG. 8 such that  
2 the endoscope 160 may be inserted through a cannula (not shown)  
3 which has been inserted through an incision may in a body wall of  
4 a patient, for example. As may be clearly seen in FIG. 8B, the  
5 illumination fibers 167 are substantially aligned with the  
6 illumination fibers 171 when the first and second tubes 162 and 164  
7 are aligned along a single longitudinal axis as shown in FIG. 8B.

8 As may be more clearly seen in FIG. 8A, the second tube 164  
9 may be rotated via the rod 166 until the central longitudinal axis  
10 of the second tube 164 is adjacent and parallel with the central  
11 longitudinal axis of the first tube 162 to thus expose an aperture  
12 168 of the first tube 162. After the tube 164 is rotated to expose  
13 the aperture 168, also exposed are a plurality of illumination  
14 fibers 171.

15 Thus, when the central longitudinal axes of the first and  
16 second tubes 162, 164 are aligned, a fiber optic light source (not  
17 shown) coupled to the illumination fibers 171 transmit light  
18 through the illumination fibers 167. The numerical aperture of the  
19 illumination fibers 171 are selected such that light is transmitted  
20 from the illumination fibers 171 and fed to the parasitic  
21 illumination fibers 167. Thus, the numerical aperture of the  
22 illumination fibers 167 is selected to be equal or greater than the  
23 numerical aperture of the illumination fibers 171.

24 When the first and second tubes 162, 164 are aligned, light is  
25 transmitted from the first illumination fibers 171 to the second  
26 set of illumination fibers 167. Thus, when the endoscope 160 is

1 inserted through a cannula (not shown), at least a portion of and  
2 preferably all of the light is coupled from the illumination fibers  
3 171 fed through the parasitic illumination fibers 167 to illuminate  
4 the region into which the endoscope 160 is being inserted.

5 The second tube 164 may be rotated via the rod 166 until a  
6 central longitudinal axis of the tube 164 is adjacent and parallel  
7 with the central longitudinal axis of the first tube 162 and the  
8 aperture 168 of the first tube 162 is fully exposed. The second  
9 tube 164 is rotated until the surface 164a is juxtaposed the  
10 surface 162a. The second tube 164 may then be retracted such that  
11 an aperture 170 of the second tube 164 is substantially in the same  
12 plane as the first tube aperture 168 (FIG. 8A).

13 When the second tube 164 is rotated to expose the aperture of  
14 the first tube, as shown in FIG. 8A, illumination fibers 171  
15 provides illumination and 167 no longer have light fed thereto and  
16 thus do not provide illumination. Those of ordinary skill in the  
17 art will now recognize that this technique may be used, for  
18 example, in conjunction with the stereoscopic endoscopic described  
19 in conjunction with FIG. 4 through 4E above or alternatively, the  
20 technique may be used in conjunction with the operative endoscope  
21 described in conjunction with FIGS. 5 through 5B above.

22 Referring now to FIGS. 8D and 8E, in an alternate embodiment,  
23 an endoscope 180 includes a tube 182 having parasitic illumination  
24 fibers 181 disposed thereon as shown. Here, the tube 182 is  
25 slightly offset about a central longitudinal axis of a first 184.  
26 Thus, as shown in FIG. 8E, only a portion of the illumination

1 fibers 181 in the tube 182 may be aligned with the illumination  
2 fibers 186 disposed about the tube 184.

3 Here the outer surface of the tube 182 includes a contoured  
4 portion 182a. The contoured portion 182 is provided having a  
5 diameter corresponding to the outside diameter of the tube 184 such  
6 that when the tube 182 is rotated via a rod 166' to expose a front  
7 portion 185 of the tube 184, the tube 182 may be retracted along a  
8 side portion of the tube 184 without interference.

9 Referring now to FIGS. 9 and 9A, an endoscope 190 includes  
10 first and second tubes 192, 194. The second tube 194 is here  
11 provided having a diameter such that substantially all of the  
12 illumination fibers 196 in the second tube 194 may be disposed to  
13 receive light from illumination fibers 198 in the first tube 192.  
14 The illumination fibers 198 are coupled to a light source (not  
15 shown). Here the outer surface of the second tube 194 is includes  
16 a contoured portion 195. The contoured portion 195 is provided  
17 having a diameter corresponding to the outside diameter of the  
18 first tube 192 such that when the second tube 194 is rotated to  
19 expose a front portion 197 of the first tube 192, the second  
20 tube 194 may be retracted along a side portion of the first  
21 tube 192 without interference.

22 Having described preferred embodiments of the invention, it  
23 will now become apparent to one of skill in the art that other  
24 embodiments incorporating their concepts may be used. It is felt,



1     therefore, that these embodiments should not be limited to  
2     disclosed embodiments but rather should be limited only by the  
3     spirit and scope of the appended claims.